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Storage Tests with Lemons in Non-Ventilated Cartons with and without Biphenyl and with and without 2,4-D and Water Wax Prestorage Treatment, December 1952 to August 1953

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Introduction

When the one-half box size fiber board carton was introduced commercially into the citrus industry of California and Arizona about two years ago, the question arose immediately as to what the performance of the carton would be in regard to refrigeration in transport.

It was generally assumed that cartons might impede cooling in transit to a much greater amount than the standard citrus box. Accordingly shipping and transportation tests were begun without delay to determine the actual importance of this phase of the carton innovation. The results of these tests have been reported from time to time.

It was only early in the second year of carton use that the first inquiries were received as to the practicability of storing lemons in cartons for periods longer than customarily required for transportation and immediate marketing. The question was not only of holding lemons in non-ventilated cartons, but also of the effects of long exposure to the fungistat biphenyl with which most of the cartons are treated in some manner. Exposure in these circumstances might favor a greater build up of biphenyl in the air surrounding the lemons than occurred in the use of biphenyl treated wraps with which some unfavorable physiological effects of biphenyl had already been observed.

The storage phase of the general problem was brought to the attention of the members of the U.S.D.A. Citrus Advisory Committee at the meeting in Orlando, March 1952. The outcome was a recommendation that some storage tests be made with lemons in cartons, the principle purpose of which would be to observe the effects on general appearance, decay, etc., and after processing, the flavor of the products made from the stored fruit.

Just at the time such tests were being setup, further inquiry came through The Refrigeration Research Foundation regarding the feasibility of storing lemons in cartons after arrival at terminal markets.

In December 1952, two rather similar series of tests on storage in cartons were initiated. These will be referred to later as Test A and Test B. The former involved the cooperation of the Bureau of Agricultural and Industrial Chemistry Laboratory of the United States Department of Agriculture in Pasadena and The Refrigeration Research Foundation in Colorado Springs, and the latter only that of The Refrigeration Research Foundation. The storage phase of both Tests A and B were completed in March 1953. Two small subsequent storage tests, referred to as C and D were completed more recently.

TEST A

Test A consisted of storage tests of lemons in cartons treated with biphenyl. After storage the lemons were inspected and processed. The general elements of the test were as follows:

1. Three types of biphenyl application.
2. Control lemons held in standard boxes, untreated with biphenyl.
3. Three storage periods, four, eight, and twelve weeks.
4. Twelve lots of lemons each of ten cartons (or five standard boxes).

In order that the lemons would be in proper condition (ripeness) for processing immediately after each storage period, special selection for maturity had to be made. It was intended to use "tree ripe", "B-silvers" and "A-silvers" for the four, eight and twelve weeks periods, respectively, but finally the selection had to be somewhat altered to the following: "Yellows", really a mixture of "tree ripe" and "B-silvers"; "light green", a mixture of "A-silvers" and "light green"; and "dark green", a mixture of "light green" and "dark green".

5. These selections were made and the lots stored at the Upland Lemon Growers Association in Upland, December 16, 1952. Room temperature 58° F. and RH about 87%.

6. All test lemons went straight from the grove to washer and were selected immediately after washing. The washing treatment was standard for the packing house, and consisting of soap-soda ash-kerosene, followed by "water wax", carrying about 200 ppm of 2,4-D. An exception in treatment was with Lot No. A 3" (below), where the lemons were removed from the "flow" between the washing and water waxing processes so that they received neither water wax nor 2,4-D.

7. Cartons were all one-half box size and non-ventilated.

(a) IP-10. International Paper Company. Biphenyl applied as phenidor-X in impregnated "collars".

(b) FP-3. Fiberboard Products, Inc. Biphenyl-lemon oil impregnated "liners" manufactured by the Crown-Zellerback Paper Company.

(c) FP-2. Fiberboard Products Inc. Biphenyl-lemon oil impregnated "pads" placed inside on top and bottom of cartons. Cartons FP-2 differed from FP-3 in that the latter were normally intended to be used with biphenyl-lemon oil impregnated "collars".

Further details of test setup, with number symbols of treatment used were as follows:

Lots A-1. Controls. Stored in standard lemon crates. Five crates for each storage period marked 1a, 1b, 1c, for 4, 8 and 12 weeks storage, respectively.

Lots A-2. Cartons. IP-10 with Phenidor-X "collars". Ten cartons for each storage period, marked 2a, 2b, and 2c, for 4, 8, and 12 weeks storage respectively.

Lots A-3. Cartons. FP-2, with biphenyl-lemon oil in "pads". Neither water wax nor 2,4-D. Ten cartons for each storage period marked 3a, 3b, and 3c, for 4, 8, and 12 weeks storage respectively.

Lots A-4. Cartons. FP-3, with two biphenyl-lemon oil "liners". Ten cartons for each storage period, marked 4a, 4b, 4c, for 4, 8, and 12 weeks storage respectively.

Lemon button analysis in storage tests

The remarks here should apply to all the storage tests described in this report.

It is generally recognized that the appearance of the buttons of lemons after periods of holding, serve as a ready and important indication of the condition of the lemon itself. If observation of the buttons of a given lot of lemons is made and recorded (tallied) at different intervals, that is, at the beginning, during and end of the storage period, the rate of change of button color from green to black can be followed and the value of the observations will be very much increased. In fact from the standpoint of what is happening inside the lemon the buttons seem to be the best early indicator of relative favorable or unfavorable influence of a storage environment. This applied especially to development of susceptability of the lemon to alternaria invasion. The common molds of course are their own immediate indicators.

In the presentation of the results of inspections of the storage lots the following classification of buttons will be used. (See p. 19, USDA Tech. Bul. No. 908, 1946 - "Changes in Lemons During Storage as Affected by Air Circulation and Ventilation" - Harvey).

1. Green (full green) (G)
2. Inter-green (I.G.)
3. Inter-black (I.B.)
4. Black (full black) (B)
5. Off (not present) (Off)
6. Alternaria and other decay recorded and used along with the button tallies in the judgment of the effects of storage conditions.

A small percentage of buttons are off in most lots direct from the grove. These "offs" may be considered of slight significance, but their number is recorded to be used as base for dealing with buttons which fall during storage and become one of the indicators of storage effects, for in many instances these buttons are equivalent to full black buttons in the tally and are usually so treated.

Inspection Results for Test A

After four weeks storage. Stored as "Yellows".

Lot A-1a. Controls. Lemon in excellent condition. Fresh in appearance, firm and good color. Buttons green. 1% decay (green mold).

Lot A-2a. Phenidor-X "collars". Good general appearance, but not quite equal to the controls. Some dark buttons, 2% decay (1% alternaria).

Lot A-3a. Biphenyl-lemon oil "pads". No water wax or 2,4-D. Dull in appearance and slightly over colored. Buttons mostly black. 3% decay (2% alternaria).

Lot A-4a. Biphenyl-lemon oil "liners". Same general appearance as Lot A-2a, 2% decay (alternaria).

Table 1. Button and decay tally. TEST A.

Four weeks storage. Stored as "Yellows".
January 13, 1953.

(Figures in table represent percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Decay	
As put down in storage Dec. 16, 1952	82	13	0	0	5	0	
	Total G + IG = 95		Total IB + B + Off + decay = 5				
Jan. 13,1953 A-1 Controls in open containers w.2,4-D	66	20	10	0	3	1	mold
	Total = 86		Total = 14				
A-2 Cartons w. Phenidor treat. "collars" with 2,4-D.	25	43	18	2	10	2	1 mold 1 alternaria
	Total = 68		Total = 32				
A-3 Cartons w. biphenyl treat. "pads" no 2,4-D.	3	10	22	50	12	3	1 mold 2 alternaria
	Total = 13		Total = 87				
A-4 Cartons w. biphenyl treat. "liners" with 2,4-D.	9	45	27	2	15	2	alt.
	Total = 54		Total = 46				

Lots arrayed as to descending value of: Green + inter-green buttons: A-1 (86%); A-2 (68%); A-4 (54%); A-3 (13%);
And as to descending order of: Full black + off + decay: A-3 (60%); A-4 (14%); A-2 (9%); A-1 (1%); (-5% off).

The button tally shows that where the lemons were not protected from biphenyl by 2,4-D and water wax (Lot A-3), the buttons changed toward black most rapidly, 50% of the buttons attaining the full black category (Table 1). Of the lots in cartons, the fruit treated with 2,4-D (Lot A-2) showed the slowest button color change, and in this lot the full greens changed over to the inter-green category, swelling it from 13% to 43%, and of course some from of the original inter-green had gone over into the inter-black and black categories, but only 2% to the latter. Lot A-2 appeared definitely in the best condition of the three cartoned lots but was followed rather closely by Lot A-4, which was also treated with 2,4-D but had biphenyl treated "liners" instead of "collars".

After eight week's storage.

The general appearance of all lots at the second withdrawal was very good except Lot A-3, which had no prestorage treatment with 2,4-D and water wax. (Table 2) The presence in this lot of over 90% black buttons detracted from its appearance, while the other lots had mostly green buttons and no decay. The "light green" lemons after this eight weeks storage period were in better condition than the "yellows" from the four weeks period.

Table 2. Button and decay tally. TEST A.

Eight weeks storage. Stored as "Light Greens"
February 10, 1953.

(Figures in table represent percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Decay	
As put down in storage Dec. 16,1952	36	56	0	0	8	0	
	Total = 92			Total = 8			
Feb. 10, 1953 A-1 Controls in open containers with 2,4-D	27	58	6	0	9	0	
	Total = 85			Total = 15			
A-2 Cartons with Phenidor treat. "collars" with 2,4-D. IP-10.	45	37	14	1	3	0	
	Total = 82			Total = 18			
A-3 Cartons with biphenyl treat. "Pads", no 2,4-D. FP-2	0	1	3	91	4	1	Alt.
	Total = 1			Total = 99			
A-4 Cartons with biphenyl treat. "liners" with 2,4-D. FP-3	21	59	15	0	5	0	
	Total = 80			Total = 20			

Lots arrayed as to descending value of: Greens + inter-green buttons:
A-1 (85%); A-2 (82%); A-4 (80%); A-3 (1%).
Full black + off + decay - 8% original off:
A-3 (91%); A-4 (12%); A-2 (10%); A-1 (7%).
Black and inter-black: A-3 (94%); A-4 (15%); A-2 (15%); A-1 (6%).

After twelve weeks storage.

All lots other than A-3 (without 2,4-D and water wax protection) were in excellent condition as to general appearance, firmness and color (Table 3). No decay was present in any lot. However, A-3 showed over 50% full black buttons, the other lots were mostly free of dark buttons.

Lot A-4 with biphenyl "liners" showed 6 - 7% "biphenyl burning" of the rind. The lemons and the parts involved were adjacent to the bottom of the carton. "Dark green" lemons seem to be the most subject to "biphenyl burning".

Again as for the eight weeks storage, the excellent appearance of the lemons showed that the selections were stronger than necessary for the length of storage period. "Light green" lemons would have been adequate for twelve weeks also.

Table 3. Button and decay tally. TEST A.
Twelve weeks storage. Stored as "Dark Greens"
March 10, 1953.

(Figures in table represent percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
As put down in storage Dec. 16, 1952	57	41	0	0	2	0
	Total = 98			Total = 2		
March 10, 1953 A-1 Controls in open cont. with 2,4-D	43	49	3	0	5	0
	Total = 92			Total = 8		
A-2 Cartons with Phenidor treat. "collars" with 2,4-D.	31	57	9	1	3	0
	Total = 88			Total = 13		
A-3 Carton with biphenyl "pads" with no 2,4-D	1	20	18	56	5	0
	Total = 21			Total = 79		
A-4 Carton with biphenyl "liners" with 2,4-D	41	45	12	0	2	0
	Total = 86			Total = 14		

Lots arrayed as to descending percentages of green + inter-green buttons:
A-1 (92%); A-2 (88%); A-4 (86%); A-3 (21%)
Full black plus inter-black + off + decay, - 2% originally off:
A-3 (77%); A-4 (12%); A-2 (11%); A-1 (6%).

The results of the button tallies for the three storage periods of Test A are summarized by means of Charts 1 and 2 which show arrays of all the storage lots according to the categories of green plus inter-green buttons (Chart 1) and black plus decay plus off buttons (Chart 2).

1. Green plus inter-green buttons. A glance at Chart 1 shows (by the lemon button indication) the best to worst storage condition provided, although little beyond the fact that one condition favors the preservation of button color more than another. The order shown from best to worst was: A-1 Controls; A-2 (Phenidor "collars"); A-4 (biphenyl "liners"; and A-3 (biphenyl "pads" but no 2, 4-D or water wax).

2. Black plus decay plus off buttons: The graphs of Chart 2 are not corresponding supplements or reciprocals of those of Chart 1. Two elements are lacking; (a) inter-black buttons, because they indicate only the phase between the first visible attack of alternaria and the complete conquest of the button ("full black" or "off"); and (b) the percentage of originally "off" buttons which do not usually indicate other than a careless picker, but the number is recorded and used as a basis for dealing with buttons which fall during storage and usually are considered equivalent to full black ones. Chart 2 shows a spread of differences between lots which takes on more significance, because it indicates better, not only what has happened but also what portion of the lemons are becoming definitely unsafe for shipping. However, the order from best to worst is the same as shown by the percentage of green buttons.

Processing

The processing of the test lemons after storage and inspection was done by the Bureau of Agricultural and Industrial Chemistry Laboratory in Pasadena. At the end of each storage period the lemons were taken immediately to this laboratory before opening the cartons. After arrival they were opened, the fruit inspected and turned over for processing. The results obtained from the products will be reported by the Bureau of Agricultural and Industrial Chemistry Laboratory, but a brief description of the procedure selected follows:

The lemons of each lot were washed, juiced, and dissolved air removed by an accepted method. The juice was then divided into two equal amounts: (a) Filled into enamel-lined six ounce cans, pasteurized in a shaking water bath at 180°F. for 2½ minutes, and rapidly cooled in running water. This became the single strength juice half. (b) The proper amount of sugar added, filled into enamel-lined six ounce cans and quick-frozen. This became the lemonade base half.

The single strength juice samples were then stored at 70°F. and the frozen lemonade base samples at 0°F. The storage periods chosen were 0, 6, and 12 months. After each storage period biphenyl determinations and other tests were or will be made on the samples. Taste tests were made using the triangular taste technique (two identical and one odd sample).

The last samples from the 12 months juice storage will not be ready for examination until March 1954. However, Dr. E. A. Beavens, in charge of the Pasadena Laboratory of the Bureau of Agricultural and Industrial Chemistry has kindly furnished some data from the zero storage taste tests

which are summarized in the following table where the results recorded are of course checked against the corresponding control samples.

Table 4. Taste Tests on Lemonade and Single Strength Juice Prepared from Lemons Stored in Biphenyl Treated Cartons

Zero Storage Period

Frozen Lemonade Base

	"Yellows" 4 weeks			"Light Greens" 8 weeks			"Dark Greens" 12 weeks		
	Collars	Pads *	Liners	Collars	Pads *	Liners	Collars	Pads *	Liners
	N. D.	N.D.	N.D.	5%	5%	N.D.	5%	N.D.	5%
Biphenyl, ppm.		0.18			3.0			2.7	

Pasteurized Single Strength Juice

	"Yellows" 4 weeks			"Light Greens" 8 weeks			"Dark Greens" 12 weeks		
	Collars	Pads *	Liners	Collars	Pads *	Liners	Collars	Pads *	Liners
	1%	N.D.	5%	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Biphenyl, ppm.		0.14			0.42			2.0	

N.D. = No difference in taste between samples
5% = Odds of 19 to 1 that results were not due to chance
1% = Odds of 99 to 1 that results were not due to chance
* Lemons in these lots did not receive 2,4-D or water wax before storage.

TEST B

Test B consisted of storage tests of lemons in cartons with biphenyl similar to Test A, but with emphasis on the relative effects of biphenyl and 2,4-D. There was no processing following storage as there was in Test A.

It has been observed for years that lemons stored in biphenyl treated wraps in standard boxes show an increased rate of button darkening and earlier susceptability to alternaria.. On the other hand 2,4-D has been reported to have definitely the opposite effect on buttons darkening and probably one may say, hence a retarding influence on the development of susceptability to alternaria.

The details of the test arrangements were as follows:

1. All lemons used in the test were selected as "yellows" (equivalent to a mixture of "tree ripes" and "B-silvers"). Selection and storage were at the Upland Lemon Growers Association. All lots were prepared in triplicate to allow for different holding periods, which were 7, 9 and 11 weeks.

B-1 Controls. No biphenyl and no 2,4-D or water wax.
- a. Stored in open standard boxes.
- b. Stored in non-ventilated cartons.
- c. Stored in vented cartons.

B-2 Cartons. FP-2 (nonvented) with biphenyl-lemon oil "pads", no 2,4-D or water wax.

B-3 Cartons. IP-10 (nonvented) prestorage treated with 2,4-D and water wax. No biphenyl (i.e. no "collars" in cartons).

B-4 Cartons. FP-2 (nonvented) with biphenyl-lemon oil "pads" and prestorage treatment with 2,4-D and water wax.

Inspection Results for Test B
After seven weeks storage - (Table 5)
December 16, 1952 to February 5,1953

Lot B-1a. Controls. Rather high color, but firm, and otherwise good appearance.

Lot B-1b. and c. Controls. Better color and general appearance than B-1a.

Lot B-2. Biphenyl only. Firm and of good general appearance, except as detracted from by the presence of mostly black buttons.

Lot B-3. 2,4-D plus water wax. Firm and good color and very good general appearance. A few black buttons. The best lot.

Lot B-4. Biphenyl plus 2,4-D. Firm, good color, good general appearance.

The button and decay tally follows:

Table 5. Button and decay tally. TEST B.

Seven weeks storage. Stored as "Yellows"
December 16, 1952.

(Figures in table represent percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Alt. Decay
As put down in storage Dec. 16, 1952.	75	19	2	0	4	0
	Total = 94		Total = 6			

Table 5 continued.

Lot	Green	Inter-green	Inter-black	Black	Off	Alt. Decay
Feb. 5, 1953 Controls 1a. Unwrapped open	1	2	13	63	17	4
	Total = 3		Total = 97			
Controls 1b. Unvent. carton	1	1	14	72	9	3
	Total = 2		Total = 98			
Controls 1c. Vent. carton	2	2	24	57	13	2
	Total = 4		Total = 96			
Biphenyl only. 2. Non-vent carton	0	2	4	74	11	9
	Total = 2		Total = 98			
2,4-D only 3. Non-vent. carton	57	23	10	5	5	0
	Total = 80		Total = 20			
Biphenyl + 2,4-D 4. Non-vent carton	39	27	21	7	6	0
	Total = 66		Total = 34			

Lots arrayed as to descending percentages of:
Green + inter-green buttons (the three control lots combined):
B-3 (80%); B-4 (66%); B-1 (3%); B-2 (2%).
And as to ascending percentages of full black + "off" + decay - 4% original "off": (Average of the control lots combined) Order of lots, best to worst:
B-3 (6%); B-4 (9%); B-1 (76%); B-2 (90%)
Chart 3 presents an array as determined by the button tallies.

Inspection Results for Test B
After nine weeks storage -(Table 6.)

The general appearance of these storage lots seemed about the same as for the seven weeks storage, at least the lots had the same relative position as to appearance. A general change in the lots as a whole was indicated only by the button and decay tally, which shows an increase in percentages of black buttons and decay.

Table 6. Button and decay tally TEST B

Nine weeks storage. Stored as "Yellows"
February 19, 1953

(Figures in table represent percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Alt. Decay
As put down in storage Dec. 16,1952.	75	19	2	0	4	0
	Total = 94		Total = 6			
Feb. 19, 1953 Controls 1a. Unwrapped open	0	2	11	72	11	4
	Total = 2		Total = 98			
Controls 1b. Unvent. carton	1	1	4	84	4	6
	Total = 2		Total = 98			
Controls 1c. Vented carton	0	0	3	83	9	5
	Total = 0		Total = 100			
Biphenyl only 2. Non-vent. carton	0	0	3	83	9	5
	Total = 0		Total = 100			
2,4-D + water wax 3. Non-vent. carton	22	46	19	6	7	0
	Total = 68		Total = 32			
Biphenyl + 2,4-D 4. Non-vent. carton	22	34	27	10	4	3
	Total = 56		Total = 44			

Lots arrayed as to the descending percentages of:
Green + inter-green buttons (the control lots combined):
B-3 (68%); B-4 (56%); B-1 (1+%); B-2 (0%)
And as to descending percentages of: (Control lots combined)
Black + off + decay - 4% of original off:
B-2 (93%); B-1 (86%); B-4 (13%); B-3 (9%)

Inspection Results for Test B
After eleven week's storage -(Table 7)

Again the general appearance of the lots after eleven week's storage seemed but little altered from those of the seven and nine week's storage and the relative position of the lots remained the same. The control lots, especially, held to the general appearance standard shown in the two previous storage periods, but lots B-2, B-3 and B-4 had generally declined somewhat in appearance and showed more decay than the button tally itself seemed to fully indicate.

Table 7. Button and decay tally. TEST B
Eleven week's storage. Stored as "Yellows"
March 5,1953.

(Figures in table represent percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Alt. Decay
As put down in storage Dec. 16,1952	75	19	2	0	4	0
	Total = 94			Total = 6		
March 5,1953 Controls 1a. Unwrapped open	0	4	11	69	11	5
	Total = 4			Total = 96		
Controls 1b. Unvent. carton	0	4	3	79	7	7
	Total = 4			Total = 96		
Controls 1c. Vent. carton	0	3	4	75	8	10
	Total = 3			Total = 97		
Biphenyl only 2. Non-vent. carton	0	2	1	80	6	11
	Total = 2			Total = 98		
2,4-D + water wax 3. Non-vent. carton	34	39	14	7	5	1
	Total = 73			Total = 27		
Biphenyl + 2,4-D 4. Non-vent. carton	46	25	13	6	6	4
	Total = 71			Total = 29		

Lots arrayed as to the descending percentages of:
Green+ inter-green buttons (the control lots combined);
B-3 (73%); B-4 (71%); B-1 (4%); B-2(2%)
And as to the descending percentages of:
Full black + off + decay - 4% original (control lots combined):
B-2 (93%); B-1 (86%): B-4 (12%); B-3 (9%)

The three types of controls used in Test B varied somewhat among themselves as to performance but not consistently, and apparently without significance. It would seem that the control lemons behaved about the same when held in open standard boxes or in cartons non-ventilated or slightly vented (6-1¼ inch holes at top and bottom of each carton). In every instance the performance position of the controls lay between that of lots B-2 (biphenyl only)and lots B-4 (biphenyl plus 2,4-D). Lots B-2 were always the worst and lots B-3 (2,4-D and "water wax" only), always the best for each storage period.

TEST C

One of the aims of Test C was to observe any effects of biphenyl which might remain in the treated "pads" after eleven weeks of storage in Test B. That is to say some of the "pads" from the latter test were re-used in Test C. An additional element of the test was the comparison of "water wax", 2,4-D and the residual biphenyl. The treatment of the different lots was as follows:

1. Control, with no biphenyl, no 2,4-D and no "water wax".
2. Biphenyl with no 2,4-D or "water wax".
3. Biphenyl with 2,4-D and "water wax".
4. "Water wax" with no biphenyl or 2,4-D.
5. Biphenyl and "water wax", with no 2,4-D.

The lemons for the test were selected March 5 at the San Dimas Lemon Association as "yellows" (rather a mixture of tree ripe and B-silvers). The water wax and 2,4-D of Lot 3 was applied from the regular commercial mixture, one-half percent emulsion of the former and 200 ppm. of the latter. The water wax was applied from a specially prepared one-half percent emulsion without 2,4-D.

The above lots were placed in one of the laboratory storage rooms, March 6 and held at 58°F. and 87-88% R.H., during the first period of seven weeks.

The general appearance of all lots after seven weeks was very good, firm and mostly green buttons. The control lot showed 2 percent alternaria rot and 5 percent blue mold for a total of 7 percent decay (Table 8). Lot 2 (biphenyl only) showed 2 percent alternaria rot and in the three remaining lots there was no decay.

A summary of the button tally for the seven week's storage is given in Table 8.

Table 8. Button and decay tally. TEST C

Seven week's storage. Stored as "Yellows"
March 6 to April 27, 1953.

(Figures in table are percentages)

Lot	Green	Inter-green	Inter-black	Black	Off	Alt. Decay
As divided and put down in storage March 6, 1953.	72	28	0	0	0	0
	Total = 100		Total = 0			

Table 8 continued.

Lot	Green	Inter-green	Inter-black	Black	Off	Alt. Decay
1. Control, no biphenyl, no 2,4-D, no wax	38	38	13	4	0	7
	Total = 76		Total = 17			
2. Biphenyl only no 2,4-D, no wax	38	42	14	5	0	2
	Total = 80		Total = 19			
3. Biphenyl, 2,4-D and wax	55	32	11	2	0	0
	Total = 87		Total = 13			
4. Wax only, no biphenyl and no 2,4-D	45	25	25	3	2	0
	Total = 70		Total = 28			
5. Biphenyl and wax, no 2,4-D	37	29	29	5	0	0
	Total = 66		Total = 34			

Arrayed as to decreasing percentages of green + inter-green buttons (best to poorest): Lot 3 (87%); Lot 2 (80%); Lot 1 (76%); Lot 4 (70%); Lot 5 (66%). And arrayed as to the increasing percentages of black, inter-black and off buttons plus alternaria (best to the poorest):
Lot 3 (13%); Lot 1 (17%); Lot 2 (19%); Lot 4 (28%); Lot 5 (34%).

Lot 3 which received 2,4-D in "water wax" along with the biphenyl "pads" was definitely the best, and the lots without the protection of 2,4-D were the poorest. One might expect the amount of biphenyl remaining in the "pads" after an over all time of eighteen weeks to have become so reduced that it could not have much influence, but its characteristic effect on buttons is shown.

There were three subsequent inspections and button tallies in Test C after 9, 13 and 18 weeks. At the end of the 18 weeks period the biphenyl treated pads had been in use for a total of 30 weeks, yet some effect of the biphenyl on the lemons seem evident, although one pad was observed at the last inspection to be performing as a substratum for several fruiting colonies of green mold.

The general appearance of the lemons after the eighteen week's storage was poor due to over color (reddish); many dark buttons; considerable softness; and in lots 1 and 4 visible decay in top layers.

The relative progress of button color changes throughout the test are shown in charts 4 and 5, and summaries of the button tallies for the thirteen and eighteen weeks storage periods are shown in Tables 9 and 10, respectively.

Table 9. Button and decay tally. TEST C

Thirteen week's storage - Stored as "Yellows"
March 6 to June 8, 1953.

(Figures in table are percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
Put down in storage as of March 6, 1953.	72	28	0	0	0	0
	Total = 100		Total = 0			
1. Controls, no wax, no 2,4-D, no biphenyl	10	41	16	20	0	7
	Total = 51		Total = 36			
2. Biphenyl only.	14	52	17	14	0	0
	Total = 66		Total = 31			
3. Wax, 2,4-D and biphenyl	22	54	15	8	0	0
	Total = 76		Total = 23			
4. Wax only	17	38	15	27	2	2
	Total = 55		Total = 42			
5. Wax, biphenyl no 2,4-D	13	46	22	16	2	0
	Total = 59		Total = 38			

Table 10. Button and decay tally. TEST C

Eighteen week's storage - Stored as "Yellows"
March 6 to July 10,1953.

(Figures in table are percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
1. Controls, no wax, no 2,4-D, no biphenyl	4	18	18	32	0	16
	Total = 22		Total = 50			
2. Biphenyl only	5	36	18	35	0	3
	Total = 41		Total = 53			
3. Wax, 2,4-D, and biphenyl	14	46	23	14	0	1
	Total = 60		Total = 37			
4. Wax only	0	35	20	33		
	Total = 35		Total = 53			

Table 10 continued

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
5. Biphenyl, wax, no 2,4-D	3	32	25	33	2	3
	Total = 35		Total = 58			

Charts 4 and 5 show that as regards button changes, each lot kept its relative position among the others throughout the total storage period with few exceptions. Lot 1 which received no treatment deteriorated relatively rapidly after nine weeks of storage. It ended up with 30% decay, 12% of which was alternaria rot. Altogether lot 1 had about six times as much decay as any of the other lots. The decay recorded for the other lots was alternaria rot with the exception of 1% green mold in lot 4 which received water wax only. Of the five treatments in Test C the one giving the best showing was lot 3, which received biphenyl, 2,4-D, and water wax. The performance of lot 3 was followed rather closely by lot 2, which received biphenyl only. These results seemed somewhat out of line with prior observations, but the fact that the biphenyl treated pads were under a prolonged test should be taken into account. The lack of any comparable lot with 2,4-D only, or with 2,4-D plus water wax, without biphenyl also prevented the segregation of the effect of biphenyl from that of 2,4-D or this material and wax. The mold infections in lots 1 and 4 which had no biphenyl protection, probably also further contributed to the button deterioration in those lots as indicated especially in lot 1 in which by the ninth week had shown an accumulation of 9% mold infection, and a subsequent relatively rapid rate of button darkening.

TEST D

In the main Test D was a repetition of Test C, both as to size and treatments, but differed with regard to some elements. In the first place the cartons and the biphenyl treated collars were freshly treated at full commercial strength. The lemons used were "yellows" and selected to correspond as nearly as possible to those used in Test C.

There were again five treatments or lots set up, three of which were in common with three of Test C, but Test D had two combinations of treatments not used in Test C, namely; biphenyl and 2,4-D with no water wax, and 2,4-D and water wax with no biphenyl. Also two combinations of treatments of Test C were not used in Test D, namely; water wax, with no biphenyl or 2,4-D and one with none of the three substances.

The composition of Test D was as follows: (Treatments of Lots 1, 3 and 4, also used in Test C).

Lot 1. Biphenyl, 2,4-D and water wax. Gaylord container (GC-2) with Gaylord's own phenidor mixture treated collars (similar to Phenidor-X.)

Lot 2. Biphenyl and 2,4-D, with no water wax. Cartons as for Lot 1.

Lot 3. Biphenyl, with no 2,4-D or water wax. Cartons as for Lot 1.

Lot 4. Biphenyl and water wax, with no 2,4-D. Cartons as for Lot 1.
Lot 5. Water wax and 2,4-D, with no biphenyl. Carton, California Container Corp. (CCA-3)

The lemons used in the above lots were selected at Upland Lemon Growers Association, April 13, and the lots were prepared and stored at Upland for four weeks, but after four weeks the lots were brought to Pomona and stored in the same room as Lot C and under the same conditions. Inspections and button tallies were made after four, eight, thirteen and seventeen weeks. Summaries of button tallies are presented as follows:

Table 11. Button and decay tally. TEST D

Four week's storage at Upland
April 13 to May 11, 1953
Temperature 58°F., RH about 87%

(Figures in table are percentage)

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
As of April 13,1953	70	30	0	0	0	0
	Total = 100		Total = 0			
1. Biphenyl, 2,4-D, wax	19	55	23	2	0	1
	Total = 74		Total = 25			
2. Biphenyl, 2,4-D, no wax	32	45	18	2	2	1
	Total = 77		Total = 20			
3. Biphenyl, no 2,4-D, no wax	26	42	25	6	1	0
	Total = 68		Total = 31			
4. Biphenyl, no 2,4-D, wax	36	49	15	0	0	0
	Total = 85		Total = 15			
5. No biphenyl 2,4-D, wax	45	42	11	1	1	0
	Total = 87		Total = 12			

Table 12. Button and decay tally. TEST D

Eight week's storage - 4 weeks Upland; 4 weeks Pomona
April 13 to June 8,1953

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
As of April 13, 1932	70	30	0	0	0	0
	Total = 100		Total = 0			

Table 12 continued

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
1. Biphenyl, 2,4-D, wax	15	47	33	3	1	1
	Total = 62		Total = 36			
2. Biphenyl, 2,4-D, no wax	24	48	24	2	2	0
	Total = 72		Total = 26			
3. Biphenyl, no 2,4-D, no wax	14	41	22	22	1	0
	Total = 55		Total = 44			
4. Biphenyl no 2,4-D, wax	26	51	20	3	0	0
	Total = 77		Total = 23			
5. No biphenyl, 2,4-D, wax	31	47	14	5	2	1
	Total = 78		Total = 19			

Table 13. Button and decay tally. TEST D

Thirteen week's storage - 4 weeks Upland; 4 weeks Pomona
April 13 to July 13, 1953

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
As of April 13, 1953	70	30	0	0	0	0
	Total = 100		Total = 0			
1. Biphenyl, 2,4-D, wax	12	36	42	6	1	3
	Total = 48		Total = 48			
2. Biphenyl, 2,4-D no wax	18	53	25	2	2	1
	Total = 71		Total = 27			
3. Biphenyl, no 2,4-D or wax	7	28	31	32	1	1
	Total = 35		Total = 63			
4. Biphenyl, no 2,4-D, wax	18	42	32	8	0	0
	Total = 60		Total = 40			
5. No biphenyl, 2,4-D, wax	27	45	20	5	2	1
	Total = 72		Total = 25			

Table 14. Button and decay tally, Test D

Seventeen week's storage - 4 weeks upland; 13 weeks Pomona
April 13 to August 10, 1953

Lot	Green	Inter-green	Inter-black	Black	Off	Decay
As of April 13, 1953	70	30	0	0	0	0
	Total = 100		Total = 0			
1. Biphenyl, 2,4-D, wax	8	31	48	5	2	5
	Total = 39		Total = 53			
2. Biphenyl, 2,4-D, no wax	10	42	37	5	4	2
	Total = 52		Total = 42			
3. Biphenyl, no 2,4-D or wax	1	13	19	62	2	2
	Total = 14		Total = 81			
4. Biphenyl, no 2,4-D, wax	9	21	40	28	0	0
	Total = 30		Total = 68			
5. No biphenyl, 2,4-D, wax	25	42	20	8	3	2
	Total = 67		Total = 28			

The inspection of the lemons in Test D at the close of the seventeen weeks of holding showed the general condition as follows:

Lot 1. Appearance good; color good to considerable over color (reddish); rather firm. No decay showing in the top layers, but some decay found on further inspection. To date there had been an accumulated decay of 10% of which about 4% was alternaria rot, the remainder blue and green molds.

Lot 2. Appearance about the same as Lot 1, more green buttons showing. Accumulated decay to date 4%, all of which was alternaria rot. The last four weeks of the holding period brought 2 of the 4% total decay.

Lot 3. General appearance of the lemons about as in the preceding lots, but the relatively larger amount of dark buttons showing were a detraction. Accumulated decay 3%, 2½%, of which was alternaria rot.

Lot 4. Much like lots 1 and 2 in general appearance and condition. Accumulated decay in seventeen weeks only 2%, and that alternaria rot.

Lot 5. General appearance probably the best of the five lots. This partly due to the nearly 70% green buttons showing. Accumulative decay to date, 4% of which 1% was alternaria rot.

The general ranking of the lots of Test D, from best to poorest, as judged on basis of button analysis was definitely:

5. (2,4-D + water wax);
4. (Biphenyl + water wax);
2. (Biphenyl + 2,4-D);
1. (Biphenyl + 2,4-D + water wax; and
3. (Biphenyl only)

Charts 6 and 7 show the interrelation of the button changes through the four categories. All lots keep the same relative positions assumed after the first four weeks of storage with the exception of lots 2 and 4. This exception was due partly to the slowness of button change in the former (mostly a shifting of relationship between full greens and inter-greens) and partly to the nose-dive of change in the latter after the thirteenth week. However, this exception did not alter the general overall storage picture. The great difference in the button behavior between lots 5 and 3 is striking.

Tests C and D had three treatments in common. The relative results of these treatments in the two tests are shown in Chart 8. For each corresponding pair of lots which were intended to receive the same general treatment it will be noted that the button changes are more rapid in Test D. This indicates that the effect of biphenyl in Test C had been reduced through the long holding and use of the biphenyl pads.

All the tests reported herewith should be repeated with the addition of a lot receiving 2,4-D only. That is to say, if a test of untreated fruit and fruit treated with biphenyl, 2,4-D and water wax and combinations of these treatments were carried through simultaneously, it might help better to interpret the results obtained in the tests here designated as A, B, C and D.

General Summary and Conclusion

The question of the feasibility of storing lemons in cartons at points of origin or at terminal markets prompted the four series of tests here reported. The aim of the tests was extended to include somewhat more than the original question of the effect of the carton and biphenyl treatment on the storage life of the lemons. Since lemons packed in half box size fiberboard cartons may have had different prestorage or prepacking handling treatments and the cartons themselves differ in the application of the fungistat, it seemed desirable to include some of these variables in the tests. Also for experimental reasons it seemed desirable to hold lemons in cartons for longer periods than would likely be called for in practice.

For these reasons the tests included different biphenyl applications to cartons with several different combinations of prestorage treatments of 2,4-D and water wax and as much as twelve to eighteen weeks holding periods. Test A, with the cooperation of the Bureau of Agricultural and Industrial Chemistry Laboratory in Pasadena, included processing and biphenyl absorption and taste tests on the lemons after storage.

The periodic inspections of the stored lemons included general appearance, color and decay, vitamin C determination, etc. and especially changes in button color which was used as a ready indicator of relative physiological condition of the lemons in relation to susceptability to alternaria rot and other storage hazards.

From the standpoint of the tallies of button changes a number of interesting things were observed, some of which had been observed before but not specifically in relation to lemons stored in cartons.

These observations may be summarized as follows:

The fungistat, biphenyl, showed rather effective control of blue and green molds but none for alternaria rot.

Biphenyl consistently speeded up the rate of change of buttons from green to black. In this action it may be safely assumed that biphenyl tended to lower the tone of the lemons thereby increased their susceptability to alternaria rot and probably to other of the common storage disorders.

The commercial 2,4-D prestorage treatment consistently showed a very favorable action toward the retardation of the darkening of buttons, and probably associated with this favorable physiological effect came a protection against the deteriorating action of biphenyl, and the invasion of Alternaria.

The commercial prestorage water wax application, aside from retarding shrinkage, did not show consistent results in regard to its effect on button darkening in combination with 2,4-D or biphenyl. Water wax used alone (Test C) or with biphenyl, without 2,4-D (Tests C and D) perhaps gave some indication that it tended to increase the rate of button darkening, but when used with 2,4-D, without biphenyl (Test D), the opposite tendency was indicated.

The favorable action of the commercial prestorage application of water wax with 2,4-D, almost counter balanced the unfavorable physiological effects of biphenyl with which the lemons later came into contact in the cartons. The preliminary data from the processing of the lemons of Test A suggest that the water wax application may retard also the absorption of biphenyl.

Were it not for the danger from blue and green molds the 2,4-D water wax application, without subsequent biphenyl, would seem at present to offer the best protection for lemons which are to be stored in cartons.

The results while showing that certain unfavorable physiological changes occur in lemons held in cartons for extended periods, they also indicate that strong lemons (picked as light or dark greens), commercially treated with 2,4-D and water wax can be stored in biphenyl treated cartons at 55° - 58°F. with reasonable safety for periods of four to eight weeks or under proper supervision and inspection even longer.

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E. A. Beavens and the Fruit and Vegetable Laboratory of the Bureau of Agricultural and Industrial Chemistry Laboratory, Pasadena, California responsible for the processing of the lemons of Test A.

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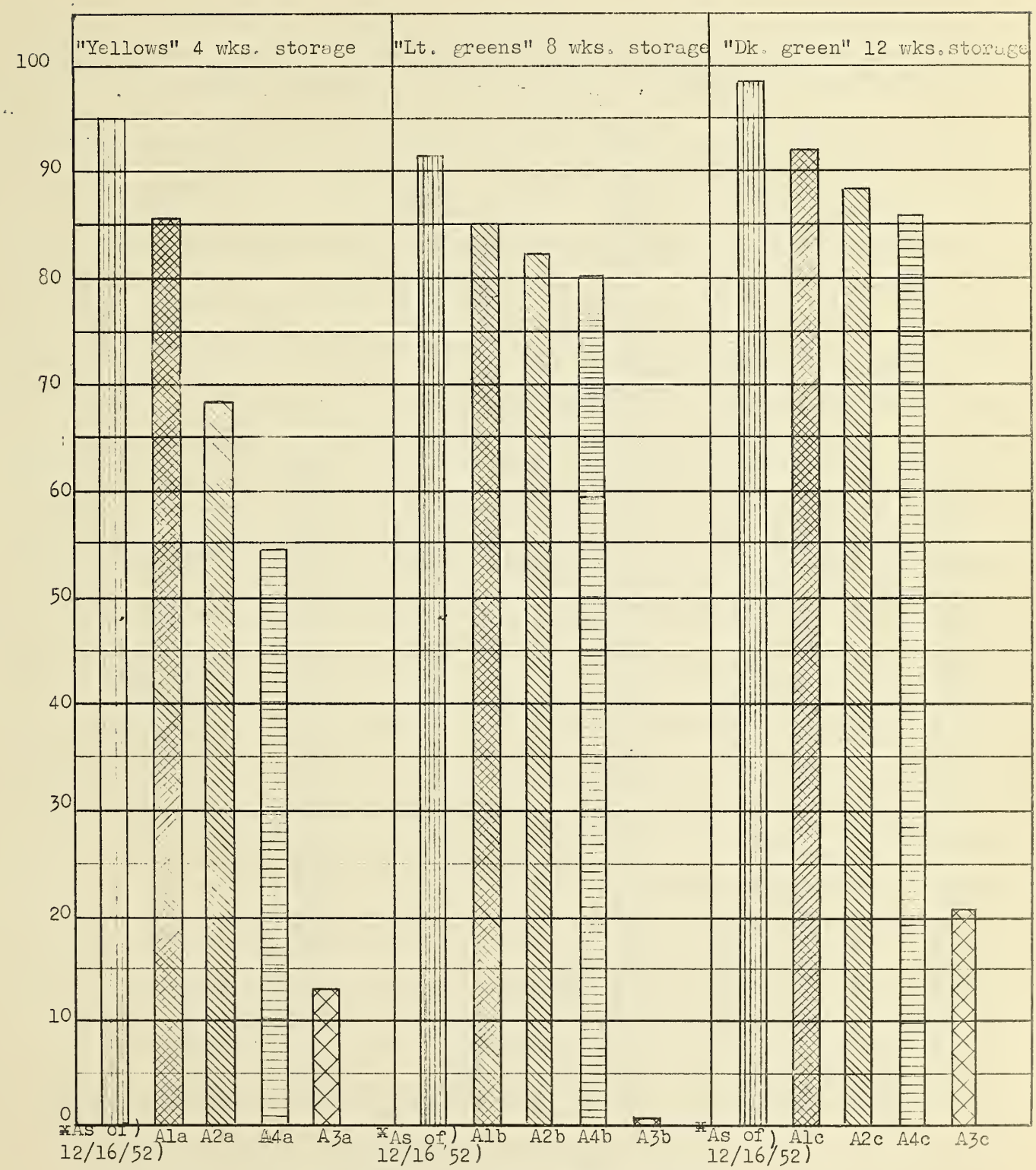
Fiberboard Products, Inc.; International Paper Company and the Crown-Zellerback Paper Company, Los Angeles, for furnishing cartons, biphenyl treated "collars", "liners", and "pads".

Harlan Barber, U. S. Horticultural Field Laboratory, Pomona, for assistance in preparing and inspecting the tests here reported.

CHART 1

LEMON STORAGE IN CARTONS - TEST A
Button tallies - green plus intergreen buttons

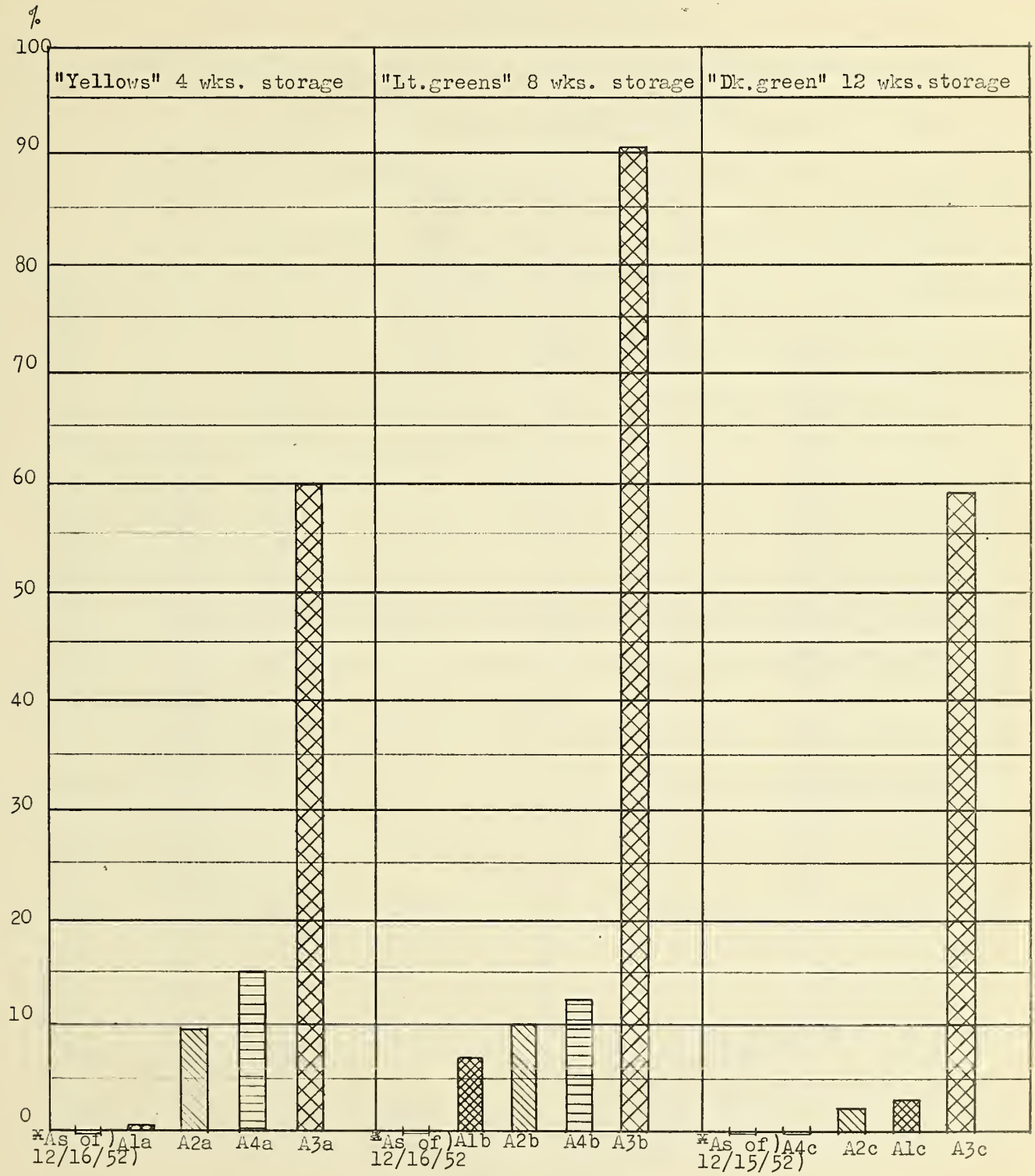


* Tally of fruit as it came from washer before storage.
A1 (a,b,c,) Control lots. No 2,4-D or wax or biphenyl; in standard boxes.
A2 (a,b,c,) Phenidor treated collars in IP-10 nonvented cartons.
A4 (a,b,c,) Biphenyl-lemon oil liners in FP-3 nonvented cartons.
A3 (a,b,c,) Bi henyl treated pads in FP-2 nonvented cartons. This fruit received no 2,4-D or wax.

CHART 2

LEMON STORAGE IN CARTONS - TEST A

Button tallies - black plus decay plus off minus the original off buttons.



* Tally of fruit as it came from washer before storage.

A1 (a,b,c,) Control lots. No 2,4-D, or wax or biphenyl; in standard boxes.

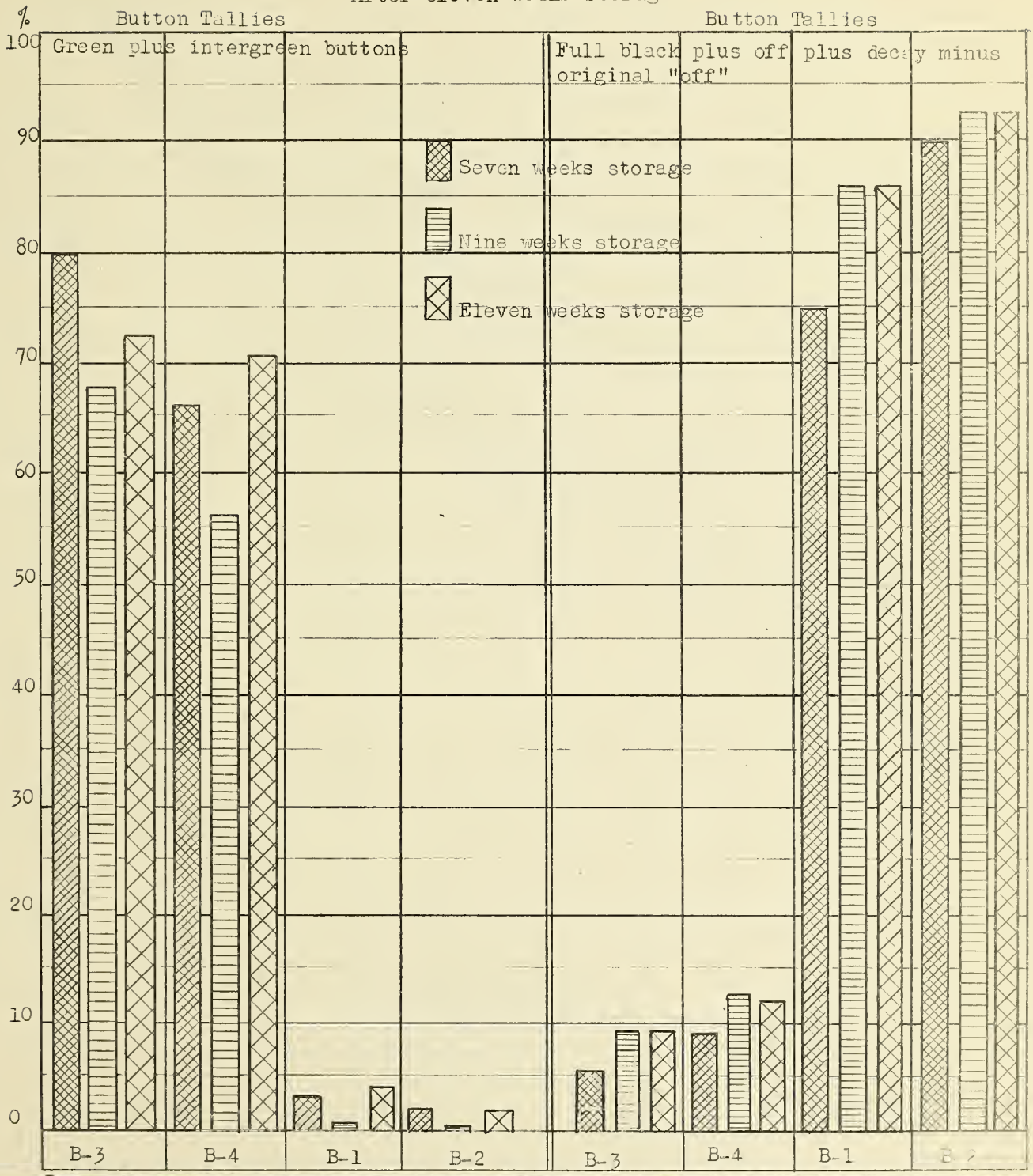
A2 (a.b.c.) Phenidor treated collars in IP-10 nonvented cartons.

A4 (a,b,c,) Biphenyl-lemon oil liners in FP-3 nonvented cartons.

A3 (a,b,c,) Biphenyl treated pads in FP-2, nonvented cartons. This fruit received no 2,4-D or wax.

CHART 3

LEMONS IN CARTONS - TEST B
After seven weeks storage
After nine weeks storage
After eleven weeks storage



B-3. Commercial treatment of 2,4-D and wax only, stored in non-vent. cartons without biphenyl.

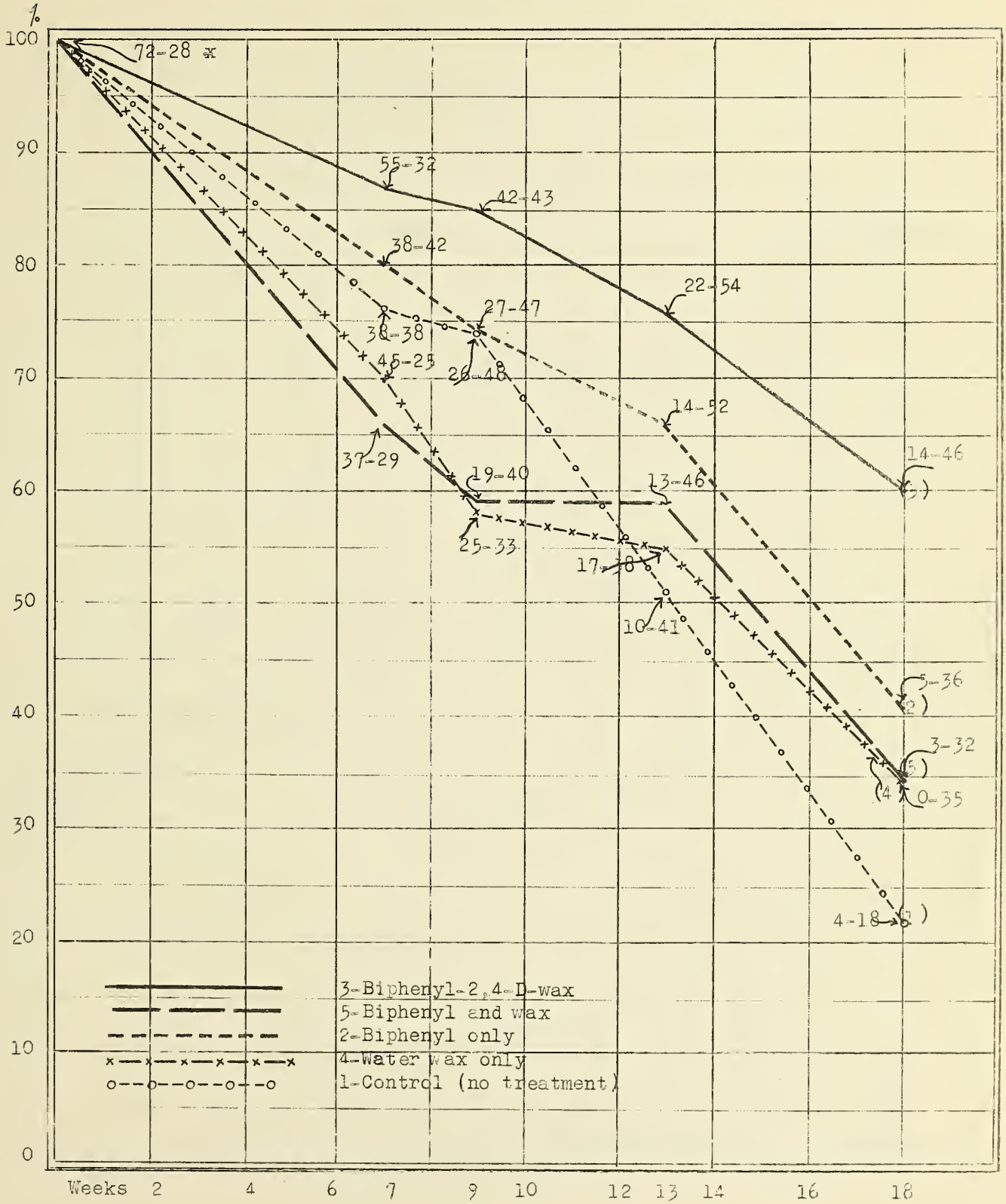
B-4. Commercial 2,4-D and wax treat. with storage in biphenyl treated cartons, non-ventilated.

B-1. Controls - no biphenyl, 2,4-D, wax. Stored in non-ventilated cartons. Average of B1a, B1b, B1c.

B-2. Biphenyl only, no 2,4-D, or wax. Stored in non-vented cartons.

CHART 4 TEST C

PERCENT GREEN PLUS INTER-GREEN BUTTONS

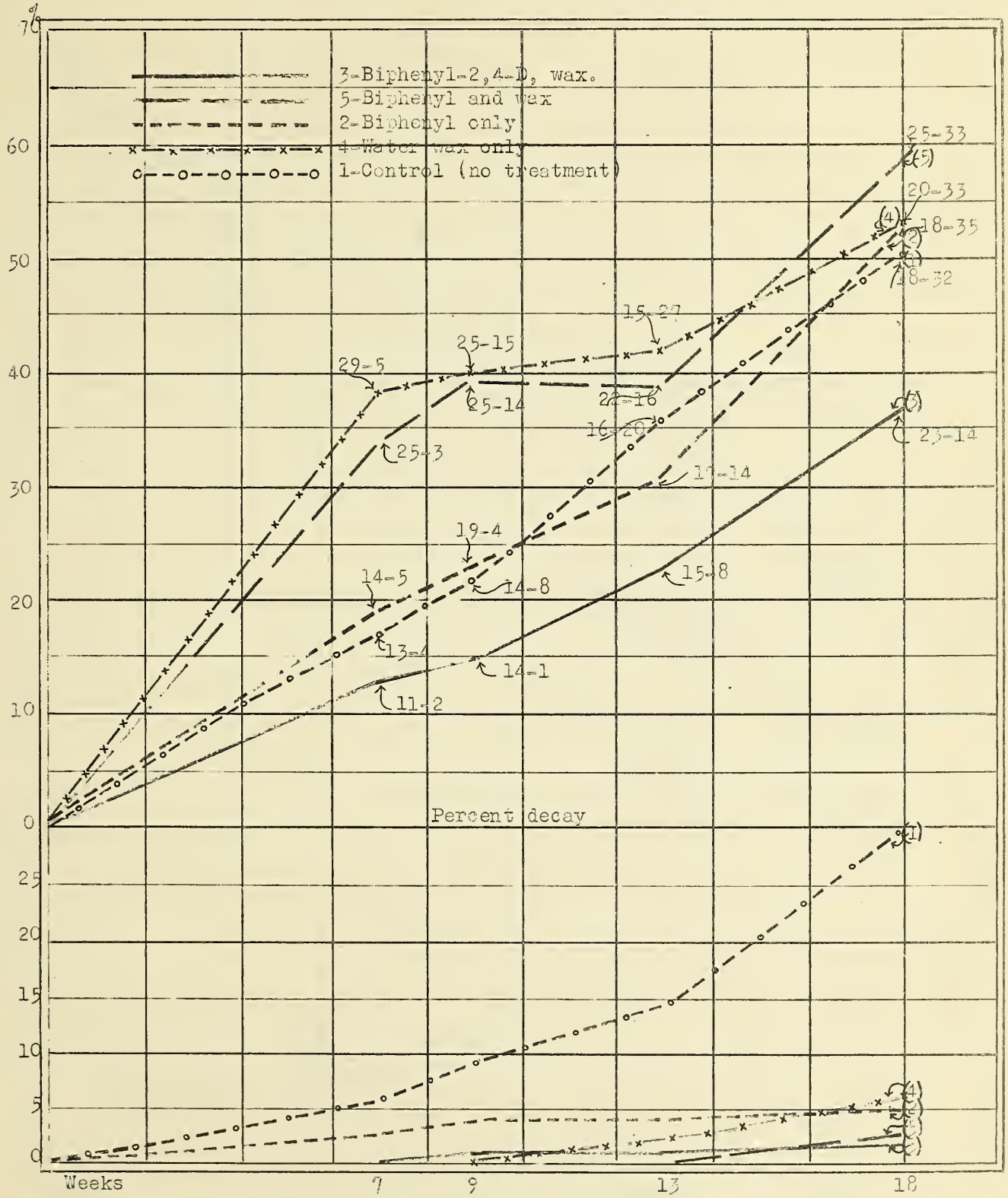


x First numbers = percent green buttons; second numbers = percent inter-green buttons

Numbers in parenthesis = lot numbers

CHART 5 TEST C

PERCENT INTERBLACK PLUS BLACK BUTTONS

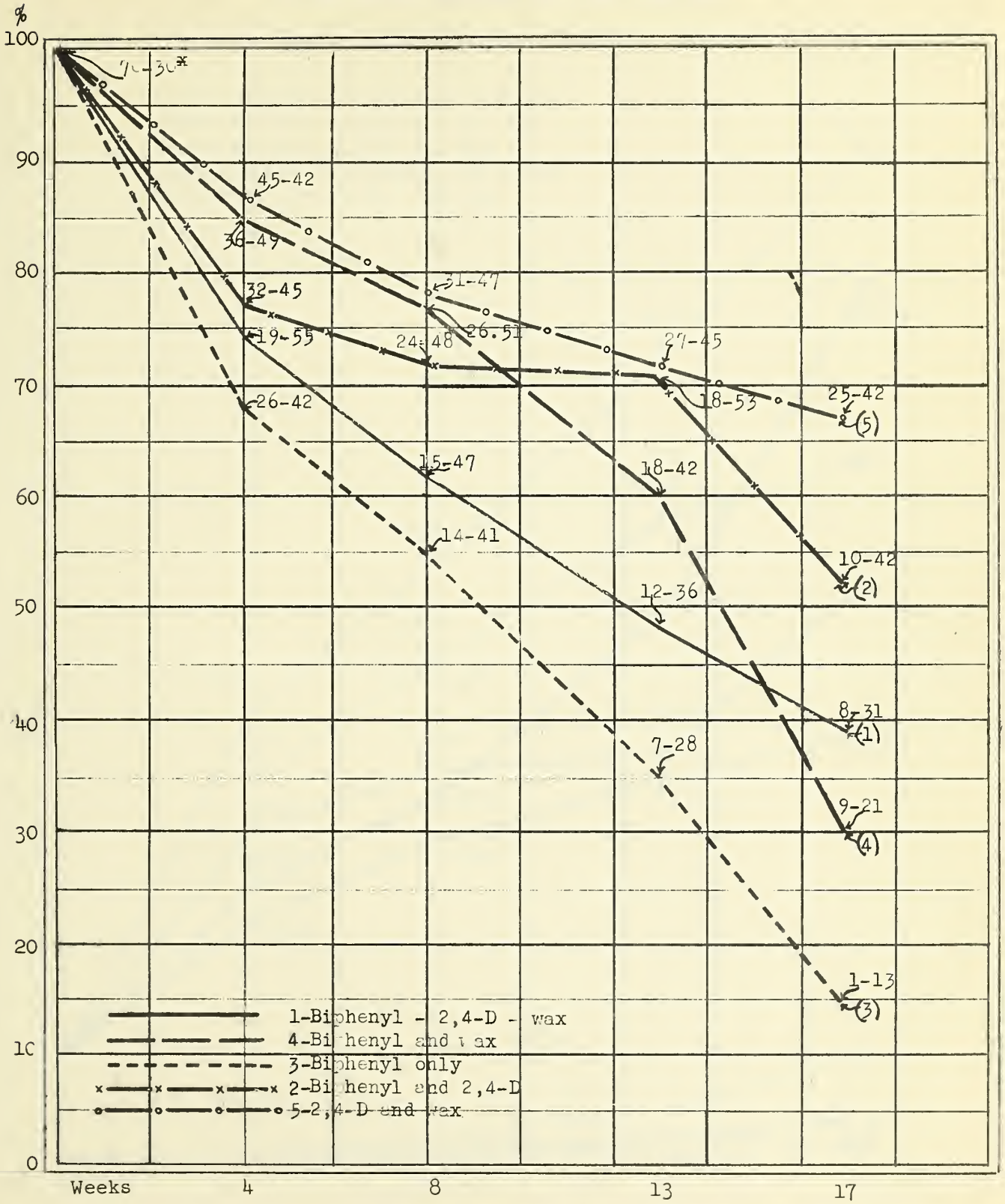


x First numbers = percent interblack buttons; second numbers = percent black buttons

Numbers in parenthesis = lot numbers

CHART 6 - TEST D

PERCENT GREEN + INTER-GREEN BUTTONS

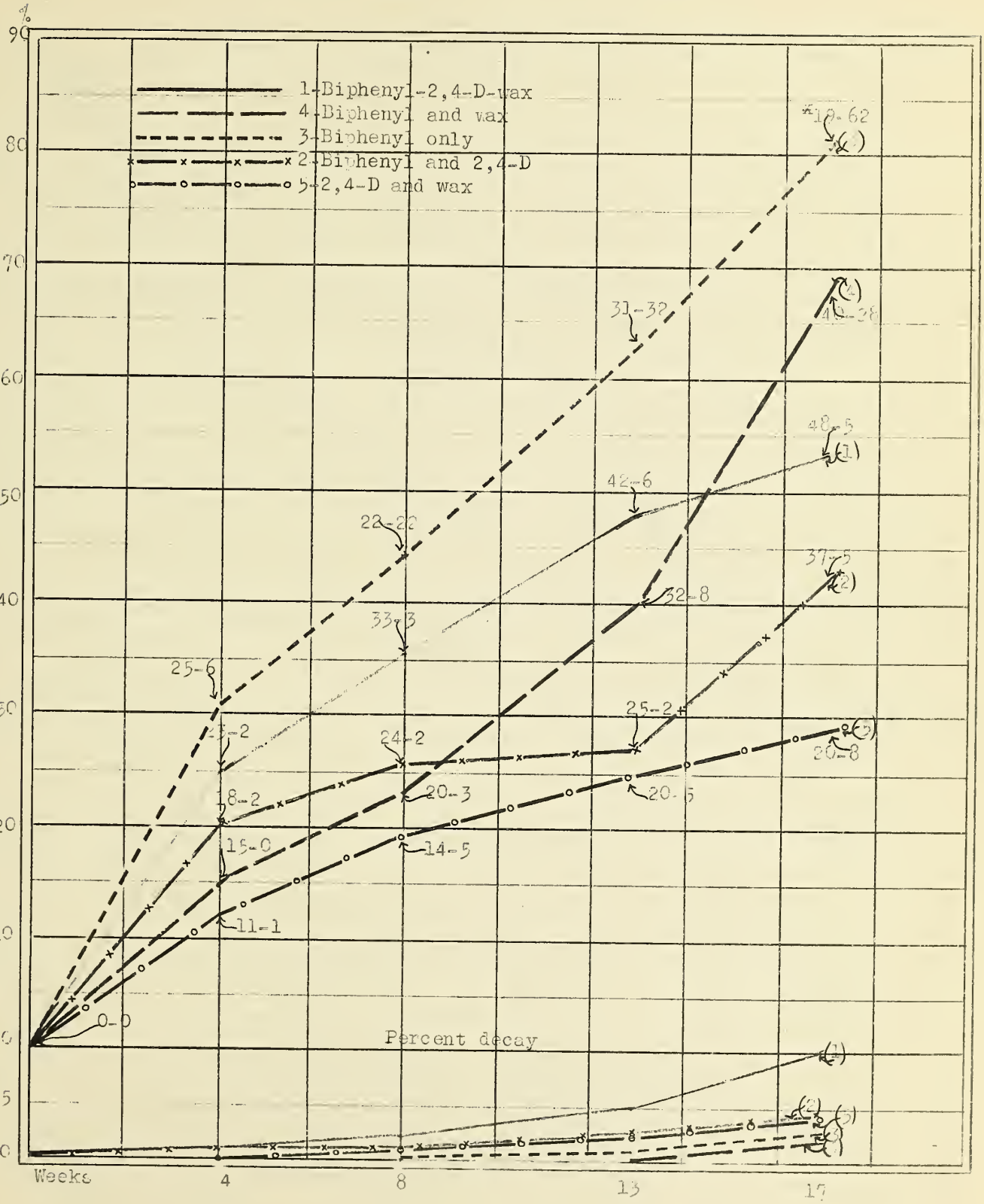


* First numbers = %green buttons; second numbers = percent inter-green buttons

Numbers in parenthesis = lot numbers

CHART 7 - TEST D

PERCENT INTER-BLACK PLUS BLACK BUTTONS



* First numbers = percent interblack buttons, second numbers = percent black buttons

Numbers in parenthesis = lot numbers

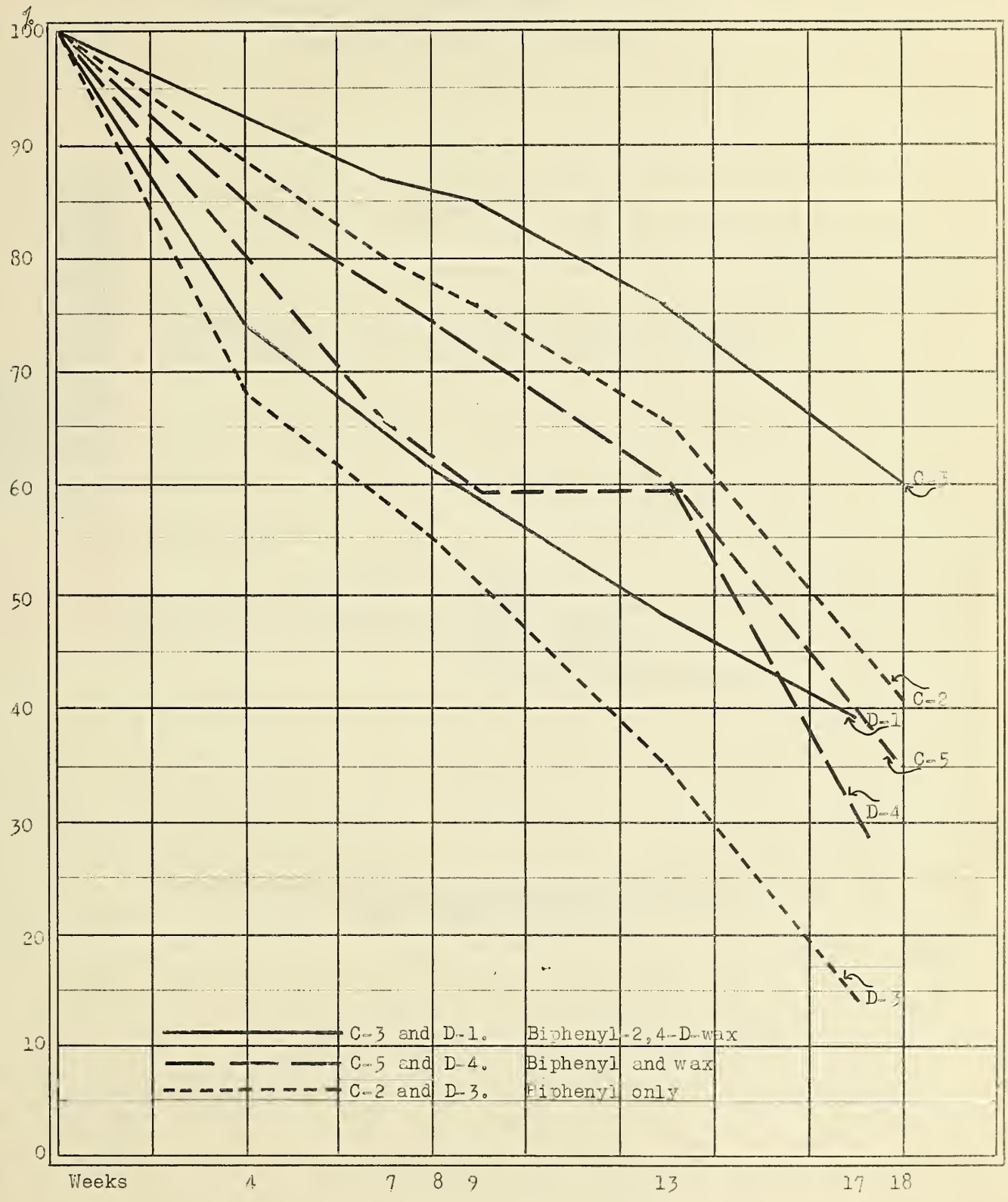



CHART 8. COMPARISON OF BUTTON CHANGES IN TESTS C AND D
Green plus intergreen buttons in the three treatments which were common to the two tests.